

Integrated 16-ps Pulse Generator based on a Reflective SOA-EAM for UWB schemes

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Abstract — A flexible pulse shaping photonic structure that is capable of generating train pulses that hold pulse widths of approximately 16-ps and a Gaussian profile at a repetition rate of 20 GHz is proposed and experimentally demonstrated. The key component is a monolithically integrated reflective SOA-EAM device that operates within the 1.55 μm frequency band. The generated pulses have low chirp, which is experimentally measured using a novel linear pulse characterization technique. The pulses have the potential to be used as seed pulses for optical ultra-wide band photonic communications systems.

Index Terms— Pulse shaping, RSOA, UWB systems, UWB applications, monolithically integrated devices.

I. INTRODUCTION

Ultrawideband (UWB) technology exploitation has been present in a vast range of application areas for some time [1] due to its versatility, potential for high data rate transmission, low power consumption, immunity to multipath fading, interference mitigation, low loss, carrier free and especially because of its spectrum cohabitation capability with other wideband and narrowband technologies, thereby negating the need for new frequency bands [2]. Although versatile and functional, since the UWB spectrum range was regulated by the Federal Communications Commission (FCC) to be allocated between the 3.1 and 10.6 GHz band with a power spectral density of -41.3 dBm/MHz [3], there is a tradeoff between the achievable data rate and coverage area. In order to meet this requirement and increase the transmission

distance, Ultrawideband over Fiber (UWBoF) has emerged as a solution based on merging this wireless technology and Microwave Photonics (MWP) not only for signal distribution [4], but also for signal generation purposes. The pulse shapes that are directly generated within the optical domain [5-7] are based on high order derivatives of the Gaussian pulse so they can meet the standard requirements. An essential component in these systems is the necessity for a seed pulse for the modulation stage, which must have a very short width and a specific Gaussian-like profile. In the case of [7] an 80-ps wide pulse was obtained using a pattern generator with a 12.5 Gb/s data rate and a 64 bit pattern sequence; in this case the seed pulse is adequate but shorter pulse width values are highly desirable. In [8] a 48.6 MHz repetition rate ultra-short pulse train (pulse width of approximately 0.48-ps) was generated by means of a Femtosecond Pulse Laser (FSPL). Although very convenient in terms of spectral bandwidth efficiency, FSPL devices are expensive and complex, so their integration into optical communication schemes is problematic.

In this letter a relatively simple photonic system that allows the generation and shaping of convenient Gaussian-like seed pulses with pulse widths in the order of 16-ps at a 20 GHz repetition rate is characterized and demonstrated. The design is based on the use of an integrated Reflective SOA-Electroabsorption Modulator (RSOA-EAM). Firstly the main functionalities of the key device and its operation are explained.

The temporal power and chirp of the generated pulses are measured using a novel linear pulse characterization technique. In this sense, the measured pulses have low chirp and have time-bandwidth products close proper of unchirped Gaussian pulses and as such are suitable for use in the before mentioned UWBoF systems. Finally conclusions explaining the efficiency of the proposal, its fit within the UWB applications field and the novelty of its characterization method are addressed.

II. PRINCIPLE OF OPERATION AND EXPERIMENT

The experimental setup is shown in Fig. 1. The RSOA-EAM # 3995 from CIP Technologies is the key device in this layout. A CW external cavity 1550 nm laser source is input to the RSOA-EAM via an optical circulator. The light passes through the multiple quantum well SOA and then to the EAM which is driven by a 20 GHz clock. The modulated light is

reflected from the opposite end of the EAM and through the SOA. The EAM acts as pulse carver, the resulting pulses have a shape and chirp that is determined by the EAM bias and modulation voltages. Generally speaking, pulses generated by EAMs usually have significant chirp, which is not desirable as it can lead to increased chromatic dispersion effects in optical transmission systems. The SOA will also induce chirp, when operated in saturation mode, however by adjusting its bias current and the input optical power the SOA induced chirp can be adjusted in such a way as to compensate the EAM chirp and thereby produce low-chirp output pulses. Also by adjusting the SOA bias and EAM bias and modulation voltage the output pulse shape can be a close approximation to a Gaussian signal. This operation holds several similarities to the proposal submitted in [9] but our solution holds significant upgrades in terms of integration capacities, suitable fitting for UWB applications and finally this work also demonstrate the reliability of the proposed characterization procedure.

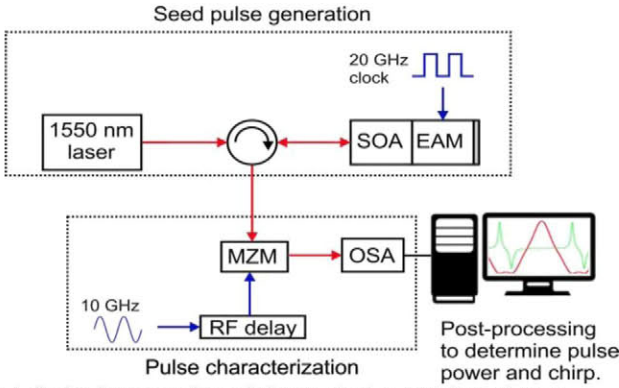


Fig. 1. Seed pulse generation and characterization experimental setup.

In this order of ideas, Fig. 2(a) shows a basic characterization of such device regarding its amplification features with current values set in a range located between 0 and 125 mA, with an optical input power and an EAM voltage with a fixed value of 0.5 dBm and -2.20 volts respectively. On the other hand, Fig. 2(b) depicts its modulation performance, where the current is now set on a fixed value and the modulation voltage varies from -3 to 0 volts. The result is the inverse effect, which means an attenuation of the input signal. This characterization although simple, it reveals how critical the bias setting in the EAM is for the output of the system and hence the achievement of the desired UWB seed pulse.

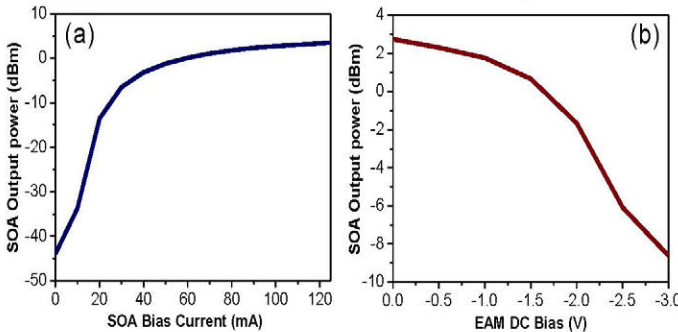


Fig. 2. RSOA-EAM characteristics. (a) Functional amplification and (b) modulation attenuation effect.

The temporal power and phase of the output pulses are

measured using a linear pulse characterization technique [10-12]. This measurement procedure basically consists of sinusoidal modulation of the RSOA-EAM output optical pulse train using a Mach-Zehnder Modulator (MZM) at half of the repetition rate (i.e. 10 GHz) of the pulse train and measuring the obtained optical spectrum. A series of optical spectra are acquired for various delays set using an RF delay line. Signal processing of the set of optical spectra is then used to determine the individual pulse temporal power and phase $\phi(t)$. The instantaneous chirp in Hertz can be calculated as $(1/2\pi)d\phi/dt$. Further mathematical details of the employed signal processing analysis can be found in [10].

In order to demonstrate the validity of the concept, pulses were generated and characterized to obtain their temporal power, chirp profiles and their energy spectra, for different input optical powers. The RSOA bias current and EAM bias voltage were 120 mA and -2.26 V respectively, which were found to give desirable pulse characteristics. The EAM was modulated by a 20 Gb/s clock obtained from a bit pattern generator with a -1.00 Vpp drive voltage.

Fig. 3 shows the pulse temporal normalized power $p(t)$ and chirp for input optical powers of -5, -2 and 0 dBm. The corresponding Full Width Half Maximum (FWHM) pulse widths are 15.4, 16.5 and 16.7-ps. The peaks in the chirp plot are caused by a phase reversal effect that occurs when the modulation voltage approaches and then departs from the EAM transmission response minima. Although these peaks cause to a large instantaneous chirp, they do not lead to significant broadening of the pulse energy spectra as they coincides with low pulse power. The pulses exhibit pedestals, which may be of some significance if the pulses are post amplified by a second SOA. The chirp in the high power portion of the pulse is low. The pulse energy spectrum is given by $|E(f)|^2$, where $E(f)$ is the Fourier transform (calculated using a fast Fourier transform) of the envelope of the normalized pulse field $E(t) = \sqrt{p(t)} \exp[-j\phi(t)]$. The energy spectra are shown in Fig. 3(d) and exhibit varying degrees of asymmetry.

The 3 dB spectral bandwidths can be obtained from the energy spectra; the resulting time-bandwidth products (TBPs) are 0.39, 0.49 and 0.43 for input optical powers of -5, -2 and 0 dBm respectively. These values are close to the TBP of 0.44 for unchirped Gaussian pulses. Fig. 4 shows that the pulse temporal power profiles are very close to the Gaussian ideal with root mean square (RMS) errors of 1.6 %, 3.0 % and 2.4 % for input optical powers of - 5, 2 and 0 dBm of respectively. Therefore, such pulses qualify as suitable seed pulses for UWB schemes such as that described in [13].

Since the main utility for these pulses is as seed modulating pulses for high order UWB generation systems, it is necessary to compare them to previously validated pulses. In this

context, the approximate 16-ps pulse widths obtained using the RSOA-EAM system show a considerable improvement compared to the 80-ps pulse widths achieved using an integrated SOA Mach-Zehnder interferometer [14].

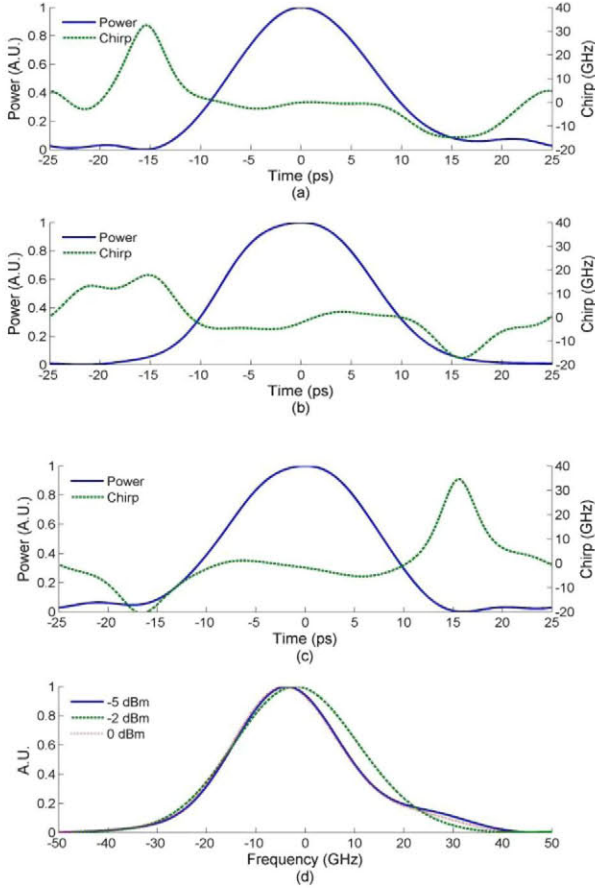


Fig. 3. (a-c) Pulse power and chirp temporal profiles for input optical powers of -5 dBm, -2 dBm and 0 dBm respectively and (d) pulse energy spectra.

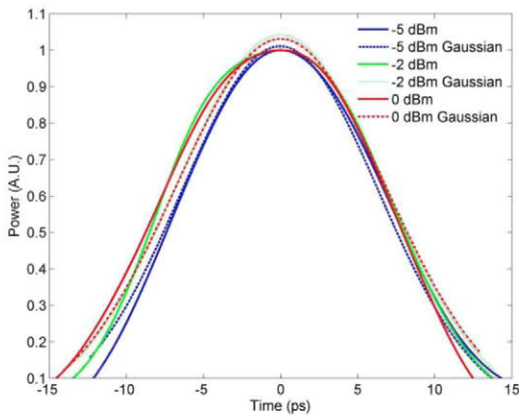


Fig. 4. Pulse power profiles and Gaussian fit.

III. CONCLUSIONS

In this work, we have proposed and demonstrated a flexible and simple setup for generation of suitable seed pulses for optical UWB communications schemes that is based on the employment of an RSOA-EAM device. The validity of the concept is verified by means of a novel pulse characterization

technique that revealed Gaussian-like 16-ps pulse widths and low chirp with time-bandwidth products close to that for an ideal unchirped Gaussian pulse. In this way, since the key component in this proposal is an integrated RSOA-EAM with high technical sensitivity in terms of the different operational points, analysis of these working stages was essential to generate the aspired waveforms. At the same time, possibility to convey this proposition into a full integrated approach is feasible and finally the solution holds potential for a wide applicability in UWBoF systems.

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